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The Los Alamos Research Quarterly is published to communicate the Laboratory's achievements and how they benefit our neighbors, our nation, and the world.

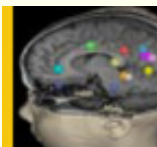
The Research Quarterly highlights our ongoing work to enhance global security by ensuring the safety and reliability of the U.S. nuclear weapons stockpile, developing technical solutions to reduce the threat of weapons of mass destruction, and solving problems related to energy, environment, infrastructure, health, and national security.

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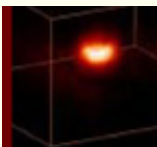
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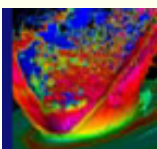
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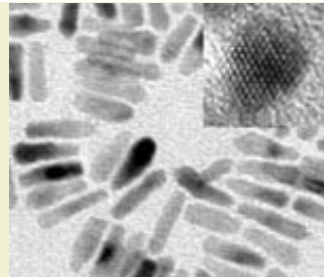
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# Dateline

Los Alamos



Bright-field and high-resolution (inset) images of cadmium-selenium quantum rods used in developing nanoscale lasers.

## Electron Microscopy Lab Adds New Instrument

From nanoscience and quantum computers to the human genome, the subjects of scientific research keep shrinking. Whether studying quantum dots and rods or bacterial toxin proteins, researchers must now understand and manipulate interactions that take place at the atomic scale—generally measured in a few nanometers, or billionths of a meter.

The Electron Microscopy Lab (EML) recently increased researchers' ability to probe such phenomena by adding a new analytical scope to its fleet of electron microscopes. The \$2.4 million FEI Tecnai F30 is a transmission and scanning-transmission electron microscope that allows researchers to see the structure of materials at very nearly the atomic scale. "In much of science, seeing is believing," said EML's Rob Dickerson, "and this is where you can do your seeing."

Electron microscopes are similar to light microscopes but focus a beam of electrons with magnetic lenses rather than refracting light through optical lenses. Also, since the electrons would be scattered by collisions with air molecules, imaging must take place in a vacuum. And given the high energy of electron beams, specimens are viewed indirectly—on a fluorescent screen, a charge-coupled device camera, or photographic film.

It is the short wavelength of electron beams that gives electron microscopes their high resolution. Because this wavelength depends on the voltage that accelerates the electrons into a specimen, accelerating voltages of 100 kilovolts or more are used. At these voltages, electrons have wavelengths of about 0.001 to 0.004 nanometer, yielding resolutions on the order of 0.1 to 0.2 nanometer, 1,000 times better than those of the best light microscope. Such resolutions can image viruses and large biological molecules and probe the atomic microstructures of materials. By contrast, the shortest wavelength of visible light

yields, at best, a resolution of 0.2 micrometer, just good enough to image bacteria.

The new Tecnai can function either as a transmission electron microscope (TEM) or as a scanning-transmission electron microscope (STEM). TEMs function like an upside-down light microscope, with electrons passing through the specimen. Image contrast is formed by elastic and inelastic scattering of the electrons within the specimen. The Tecnai has a directly interpretable point-to-point resolution of 0.21 nanometer in the TEM mode.

By contrast, in the Tecnai's STEM mode, a finely focused beam of electrons is scanned over the specimen, and an image is formed by using the transmitted beam, diffracted beams, or higher-angle inelastically scattered electrons. Images and chemical information with a resolution of 0.35 nanometer can be obtained by using the STEM mode together with detectors that analyze emitted x-rays or energy loss in the transmitted electron beam. Taken together, these capabilities make for a highly flexible microscope, thus meeting the needs of the weapons program, which provided the capital funds to purchase the instrument. One program application is to characterize plutonium alloys.

The EML is a user facility available to researchers both inside and outside the Laboratory. Current or recent EML research projects include studies of beryllium-containing aerosol samples that could relate to lung pathology in chronic beryllium disease, the structures found in uranium carbides, and the deformation microstructures found in nanolayered composite materials. The EML is also used by small businesses and is available as a forensic tool to state agencies.

Kevin N. Roark and Vin LoPresti

# Mesa View

I am pleased to share with you the third issue of Los Alamos Research Quarterly, a publication designed to highlight Laboratory research, introduce the creative people responsible for our achievements, and explain the importance of Laboratory programs to national priorities.

This year, we are celebrating our 60th anniversary. It is an honor for me to be at Los Alamos National Laboratory during this historic time. This is, in fact, a time of great opportunity, just as it was six decades ago when the Laboratory was formed amid the uncertainty of World War II.

In the following months, we will . . .

Acknowledge the past. Los Alamos holds a special place in the modern genealogy of science and technology. We are proud of our accomplishments. However, we will never rest on them or be held motionless by the past.

Accept the present. National service, mission relevance, and stewardship are core Los Alamos values, even while the world changes and we continue to change in response.

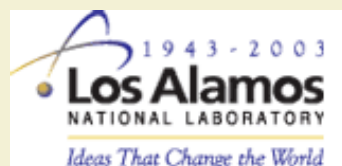
Embrace the future. Our responsibility is to help shape the future of our nation by meeting threats to national security and engaging in research to make the world a better place.

Events marking our 60th anniversary will be held throughout the year and will focus on the Laboratory's accomplishments, our future directions in science and technology, and our evolving mission. I encourage you to participate in as many of these activities as possible and help mark the Laboratory's historic contributions to national security as we renew our commitment of service to the nation.

As we celebrate the successes of our past, we will also be looking



George P. "Pete" Nanos,  
Interim Director



toward a future that is closely tied to the communities of northern New Mexico. Our continued commitment to excellence will be reflected in the successful execution of all our responsibilities. Just as for the team of scientists who worked amid the turbulence and uncertainty of World War II, our work today and tomorrow will be a source of "ideas that change the world."

This is a time of significant challenges. While maintaining scientific excellence, we must streamline and improve our business processes, take project management to higher levels of achievement, and redouble our efforts to serve our customers. We are involving our people as never before in the many changes that are underway, and we are committed to communication and transparency in everything that we do.

We are transforming the Laboratory to take our rightful place in the twenty-first century.



Brian Fishbine

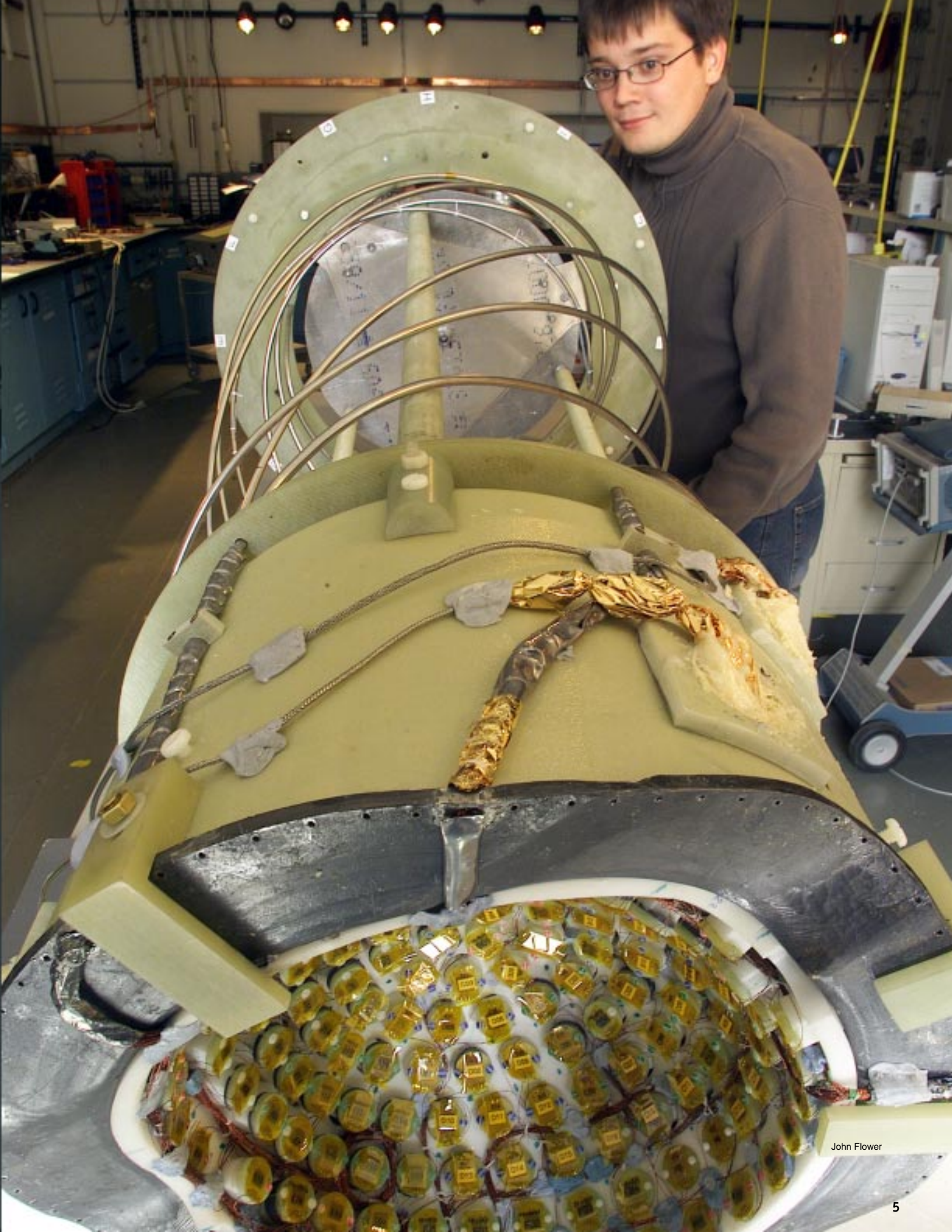
# SQUID Magnetometry

## Harnessing the Power of Tiny Magnetic Fields

Lab researchers are pioneering new medical uses for SQUIDs—superconducting quantum interference devices—from pinpointing brain tissue that causes epilepsy to monitoring fetal heartbeats.

Jonatan Mattson, a graduate research assistant, inspects the internal assembly of the MEG helmet before lowering it into a special thermos, where it will sit in liquid helium at 4° C above absolute zero. In the foreground is the array of 155 SQUID sensors that measure the magnetic fields produced by the brain's electrical activity. Low temperatures are required for the SQUID sensors to work properly. The sensors are mounted on a white plastic hemispherical shell, which fits over the top of the head.

Also visible is the brim of a lead shell that fits over the plastic shell and becomes superconducting at liquid-helium temperatures. The lead shell shields the SQUIDs from ambient fields that would swamp the brain fields.



John Flower

**M**easurements associated with the neural currents in the brain can be used to diagnose epilepsy, stroke, and mental illness, as well as to study brain function. One way to observe these tiny electrical currents is to measure the magnetic fields they produce outside the skull, a technique called magnetoencephalography, or MEG.

The traditional way to monitor the brain's electrical activity is with electroencephalography (EEG), which requires gluing as many as

150 electrodes to the scalp. MEG measures brain currents as precisely as EEG does but without physical contact, making it possible to screen large numbers of patients quickly and easily. MEG is also insensitive to the conductivities of the scalp, skull, and brain, which can affect EEG measurements.

## Enter the SQUID

Measuring the brain's magnetic fields is not easy, however, because they are so weak. Just above the skull, they have strengths of 0.1 to 1 picotesla, less

than a hundred-millionth of Earth's magnetic field. In fact, brain fields can be measured only with the most sensitive magnetic-field sensor known, the superconducting quantum interference device, or SQUID.

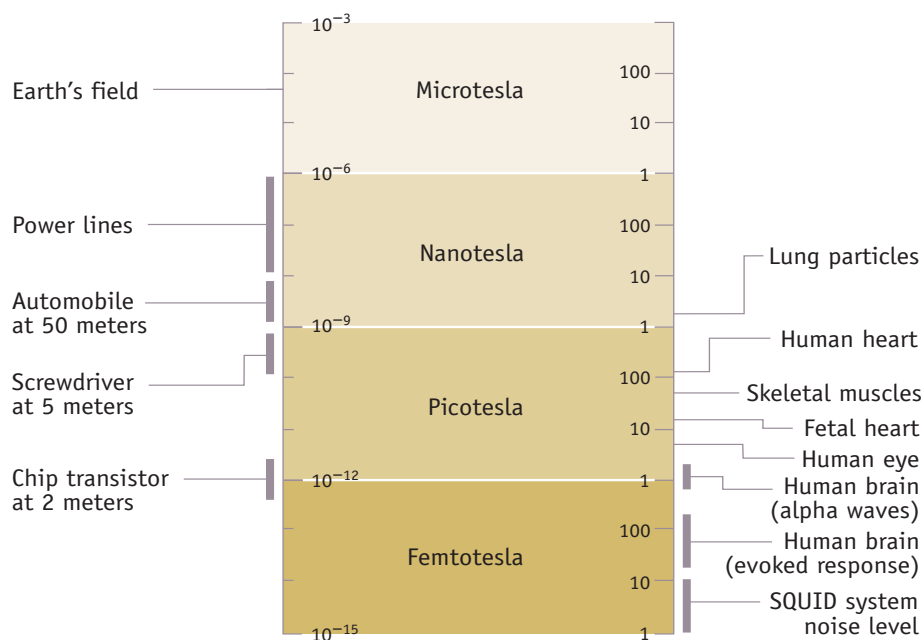
When cooled to very low temperatures, superconductors conduct electricity without resistance. This lack of resistance allows a SQUID to measure the interference of quantum-mechanical electron waves circulating in its superconducting loop as the magnetic flux enclosed by the loop changes. A SQUID can measure magnetic fields as small as 1 femtotesla.

## The MEG Helmet

Los Alamos physicists Bob Kraus, Michelle Espy, Andrei Matlachov, and Petr Volegov have built a MEG "helmet" that uses 155 SQUIDs to provide "whole head" brain-current images. The MEG helmet offers improved capabilities that could help make MEG more common in hospitals.

The SQUIDs become superconducting when immersed in liquid helium contained in a large thermos. The liquid helium cools the SQUIDs to 4°C above absolute zero. Resembling an oversized beauty-salon hair dryer, the helmet is positioned over a patient's head as he or she sits in a chair.

With sophisticated computer algorithms developed by Volegov, MEG data can be converted into current maps that give researchers an idea of where activity in the brain is occurring. Using specially designed current coils, the Los Alamos MEG system has achieved a spatial resolution of less than 0.25 millimeter. This resolution is at least four times better than that of any other MEG system, even though



Just above the skull, the brain's magnetic fields can be as small as 10 femtoteslas. Measurable brain fields are produced by an "evoked response," that is, the electrical activity produced by the brain in response to stimuli such as sounds or light flashes. To measure brain fields, SQUIDs must be shielded from the ambient magnetic fields of Earth, power lines, and other sources, or the ambient fields must be canceled electronically or by computer programs. Even the steel in a car or a screwdriver has a magnetic effect. Also shown are the magnitudes of other biomagnetic fields. Note that the heart's magnetic fields above the chest are typically 100 to 1,000 times stronger than brain fields above the head. Thus, it is much easier to measure heart rhythms than it is to measure brain fields.

other systems have up to twice as many SQUIDs.

But like other MEG systems, the Los Alamos system responds to brain-current changes in less than a thousandth of a second, adequate for most brain-current studies. The SQUIDs themselves respond in about a millionth of a second.

During a MEG measurement, the SQUIDs must be shielded from ambient magnetic fields, which tend to swamp the brain signals. Ambient fields are produced mainly by the power lines in a building, although Earth's magnetic field and even the steel in a passing car contribute. (Ferromagnetic materials like steel locally distort Earth's field.) At the frequencies of interest in brain studies—a few to several hundred hertz—the ambient fields must typically be reduced by a factor of 10,000 to 100,000.

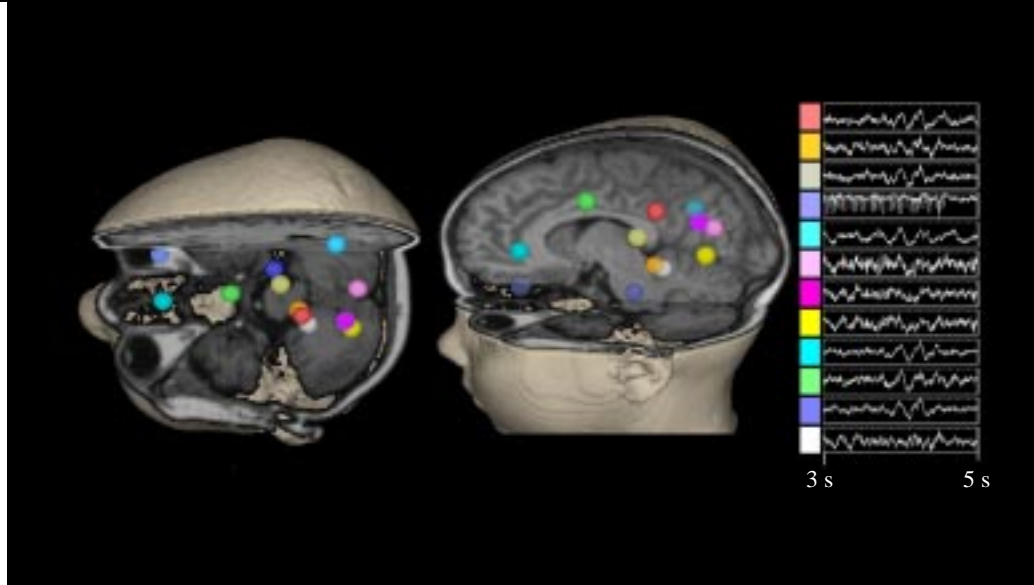
The helmet's SQUIDs are partially shielded from ambient fields by a thick, hemispherical shell of lead, which becomes superconducting at liquid-helium temperatures. Because superconductors perfectly reflect magnetic fields, the shell reduces ambient fields to as little as one-thousandth of their initial strengths. The shielding is not perfect because the shell does not completely enclose the head. The SQUIDs near the shell's crown are better shielded than those near its brim. The shell also reflects the brain's magnetic fields back to the SQUID array, increasing the helmet's sensitivity.

Usually, ambient fields are reduced by taking MEG data in a room built with large sheets of aluminum and Mumetal (an alloy with high magnetic permeability), which magnetically shield the patient. The room reduces

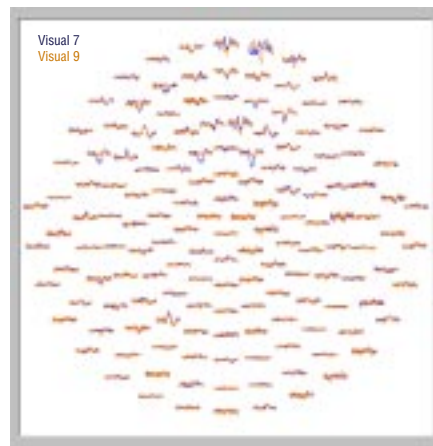
ambient fields by about a factor of 100 for frequencies near 0 hertz and by much larger factors for frequencies up to 1,000 hertz or more. The superconducting shell effectively blocks magnetic fields from zero to several thousand hertz. Thus, measurements made with the shell require only a "low-end" shielded room, which costs about \$100,000, one-fifth the cost of conventional shielded rooms.

The team has recently added external SQUIDs to the helmet that further reduce the effects of ambient fields. The external SQUIDs measure these fields at several points just outside the superconducting shell, and a computer program then subtracts the fields from the brain-field data to reduce the ambient fields' effects by another factor of 1,000—at all frequencies. The computer correction is effective because the superconducting shell shields the external SQUIDs from brain fields in addition to shielding the SQUIDs in the array from ambient fields. Thus, the external SQUIDs measure *only* the ambient fields.

After recent side-by-side comparisons with a commercial MEG system at the Veteran's Administration (VA) Hospital in Albuquerque, New Mexico, the helmet is back at Los Alamos for further development. The VA's commercial system has been used to

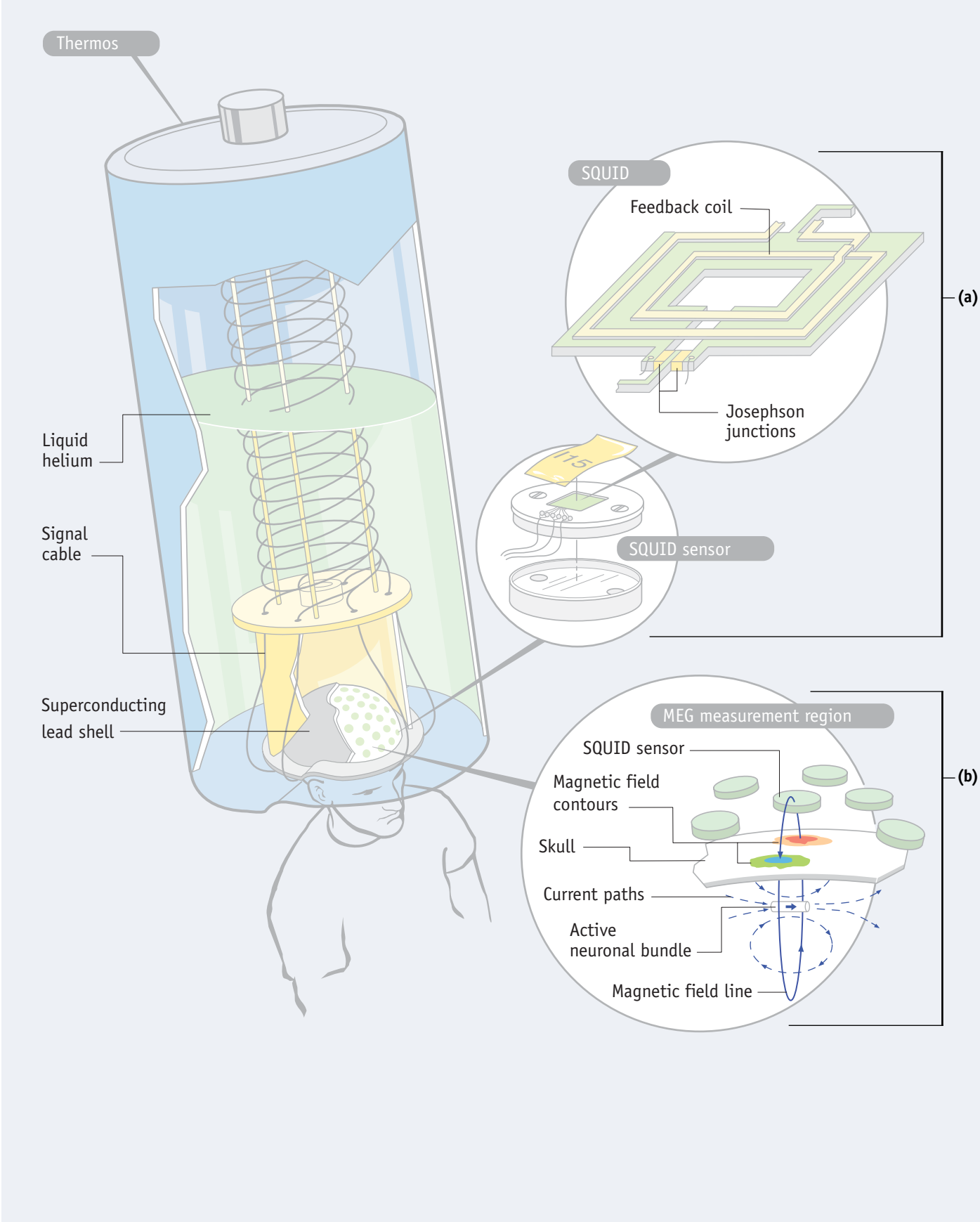


**A computer program converts the raw MEG data into maps of the brain's electrical activity as a function of time. These maps can be used to diagnose epilepsy, stroke, and mental disease and to study brain function.**



**The raw data obtained from the 155 SQUID sensors in the MEG helmet. The red waveforms (Visual 9) were obtained with the patient's eyes closed. The blue waveforms (Visual 7) were obtained as the patient observed a flashing light.**

# MEG Helmet and Measurements



The MEG helmet's array of SQUID sensors and the superconducting lead shell are cooled by immersion in liquid helium. Each SQUID sensor contains a coil of superconducting wire that receives the brain fields and is magnetically coupled to the SQUID, which produces a voltage proportional to the magnetic field received by the coil. A computer program converts the SQUID data into maps of the currents flowing throughout the brain as a function of time.

(a) The magnetic field lines that pass through the square hole at the SQUID's center determine the phases of electron waves circulating in the SQUID's superconducting region (green): the waves' interference is proportional to the magnetic flux over the hole. Since superconductors have no electrical resistance, the interference can be measured only by interrupting the superconductor with small regions that have electrical resistance—the two Josephson junctions—so that voltage drops will develop across them. The voltage measured across the junctions is proportional to the magnetic flux over the SQUID's square hole. The feedback coil magnetically couples the SQUID to the pickup coil in the SQUID sensor. A SQUID is typically 10 to 100 micrometers on a side.

(b) The colored contours show how the magnetic field produced by neural brain currents (dashed arrows) changes intensity and polarity over the skull's surface. In the red region, the field is most intense in a direction pointing out of the skull. In the blue region, the field is most intense in a direction pointing into the skull.

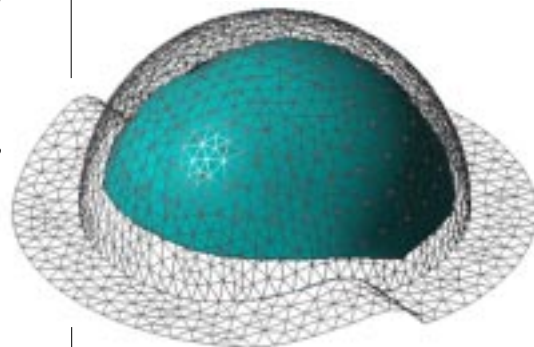
study stroke, epilepsy, schizophrenia, and brain function. Eventually, Espy says, the MEG helmet could find a home in a future Los Alamos brain-imaging facility along with EEG, magnetic resonance imaging (MRI), and other brain-imaging tools. In developing this and other medical applications for SQUIDs—such as detecting tumors and screening for disease—the team has collaborated with researchers at the Universities of New Mexico, Nebraska, and Oregon and the University of California at San Francisco.

## Controlling Seizures

In the last five to ten years, whole-head MEG systems have dramatically improved the treatment of epilepsy. For 20 percent of epilepsy patients, drugs cannot adequately control seizures, and surgically removing the brain tissue where the seizures originate—the epileptogenic tissue—is the only option. But the surgeon must know precisely where the aberrant tissue is to avoid removing nearby tissue required for motor control, sense perception, language, and memory.

A brain scan can precisely locate the epileptogenic tissue if the imaging method has high spatial resolution and is fast enough to detect the seizure discharge or the electrical activity that precedes a seizure, which also originates in the epileptogenic tissue. Although seizures occur sporadically, the electrical activity associated with them occurs continually. Thus, locating the source of these precursors can isolate the epileptogenic tissue.

Both EEG and MEG have high spatial resolution and are fast enough to detect seizure-related electrical activity,



The superconducting lead shell. The gray mesh defines the shell's contour. SQUID sensors are attached to the blue surface. At liquid-helium temperatures, the lead shell becomes superconducting and therefore an excellent magnetic shield. Because a superconductor perfectly reflects magnetic fields at all frequencies, the shell helps shield the underlying SQUID array from ambient magnetic fields. The shell also shields SQUIDs placed outside the shell from the brain's magnetic fields. These external SQUIDs provide data used to help cancel the effects of ambient fields. The superconducting shell and field cancellation method greatly reduce the cost of the magnetically shielded room required for MEG measurements, making them more affordable.



John Flower

**Los Alamos researcher Michelle Espy adjusts the MEG helmet on Michelle Martinez. Shown is the exterior wall of the helmet's thermos, which maintains the liquid helium at cryogenic temperatures. Even though the top of the patient's skull is just centimeters from a pool of liquid helium at nearly absolute zero, the thermos material insulates so well that the patient feels no discomfort.**

but sometimes the position or orientation of the electrical activity is such that MEG can locate the epileptogenic tissue while EEG cannot. In addition, by pinpointing how the brain responds to visual, auditory, tactile, or other stimuli, MEG

can help assess the effects of possible collateral damage during surgery. Along with other brain-imaging techniques, MEG is also being used to diagnose schizophrenia and stroke.

## Peering into Brain Columns

The SQUID team has also developed MicroMEG—a centimeter-long linear array of SQUIDs with a potential spatial resolution of tens of micrometers. Made of high-temperature superconductors, the array's twelve SQUIDs are cooled by liquid nitrogen instead of liquid helium. At atmospheric pressure, the temperature at which nitrogen liquefies is about 70°C higher than that at which helium liquefies. Thus, the MicroMEG array requires less thermal insulation than arrays cooled with liquid helium. As a result, the MicroMEG SQUIDs can be brought within half a millimeter of the tissue under study, allowing extremely high-resolution measurements.

MicroMEG has been used to study how impulses travel along a single nerve, such as a frog's sciatic nerve. Eventually, MicroMEG will be used to probe the electrical activity of as few as 100 to 1,000 neurons in one of the brain's cortical columns. The columns are believed to operate in parallel, like the hundreds of microprocessors in a supercomputer that work in parallel to achieve high overall speed. Such

studies will improve our understanding of brain function.

The team has also used the MicroMEG array in a highly sensitive SQUID microscope that detects flaws or defective welds in metallic nuclear-weapon parts. The SQUID microscope can detect defects invisible to ultrasound, x-rays, or traditional eddy-current methods. The metal parts are inspected to ensure that the weapons will perform as expected.

## Measuring a Baby's Heartbeats

A variant of MEG called fetal magnetocardiography, or FMCG, can be used to diagnose and treat fetal heart conditions. In fact, FMCG is the only way to measure the electrical signals produced by the heartbeat of a baby in the womb. And only the heart's electrical signals contain the detailed timing information required to diagnose and treat fetal arrhythmias.

Stethoscopes and ultrasound cannot provide this information because they use sound. Nor is electrocardiography (ECG) useful, because it directly measures the electricity produced by the heart through electrodes taped to the body. However, the baby is electrically insulated from the mother.

Around the twentieth week, Espy says, the baby's sebaceous glands secrete a waxy, white substance called *vernix caseosa*, which covers the baby's skin to protect it from amniotic fluid in the womb. Because the *vernix* is electrically insulating, electrical signals from the baby's heartbeat cannot pass into the mother's body for measurement on her skin. However, the magnetic fields produced by the baby's heartbeat pass easily through the *vernix* and can

be measured with FMCG. Although in principle ECG could be used before the *vernix* forms, the fetal heart is then too small to produce a detectable electrical signal.

Espy says that fetal heart conditions detected with FMCG can often be treated before the baby is born, or if surgery is required, the necessary equipment and specialists can be on hand at birth. And unlike other medical diagnostic techniques, FMCG poses no risk to the unborn baby or the mother. X-rays can harm even adults, and amniocentesis is invasive, with potential risk to the fetus. FMCG, however, merely receives the magnetic signals sent out by the baby's heart. FMCG is passive, noninvasive, and harmless.

The team acquired some of its MCG expertise while developing a hand-held battlefield MCG monitor. The device will allow a medic to monitor the heart rhythms of wounded soldiers without moving them or removing their clothing. The monitor can be portable because the heart's magnetic fields above the chest are about 100 to 1,000 times stronger than the brain's magnetic fields above the skull. Using advanced SQUID-sensor designs and ambient-field cancellation techniques, the team has built a hand-held MCG monitor that needs no shielding at all. The SQUID can be cooled by liquid nitrogen or an electric cryocooler. The same technology could also be incorporated in a small monitor for clinical use in a doctor's office.

From measuring brain currents and heartbeats to inspecting welds in nuclear weapons, the Los Alamos SQUID team is exploring the potential of tiny magnetic fields to solve a host of medical and defense problems. ■

## SQUID Team's Unusual Origins

**R**esearch on SQUID magnetometry at Los Alamos has its roots in personal frustration. In the mid-1980s, the wife of Lab physicist Ed Flynn suffered a heart attack that left her in a coma, and she died eighteen months later. Frustrated that doctors could not determine the condition of her brain during that time, Flynn sought and received support from John Browne—then the Physics Division Leader—to investigate the use of SQUIDs for imaging brain function. Gathering experts in cryogenics and the life sciences from around the Laboratory, Flynn formed a neuromagnetism group for this purpose. Initial measurements with a single SQUID were followed by increasingly sophisticated multi-SQUID systems. A major breakthrough was the group's development of the superconducting-shell concept.

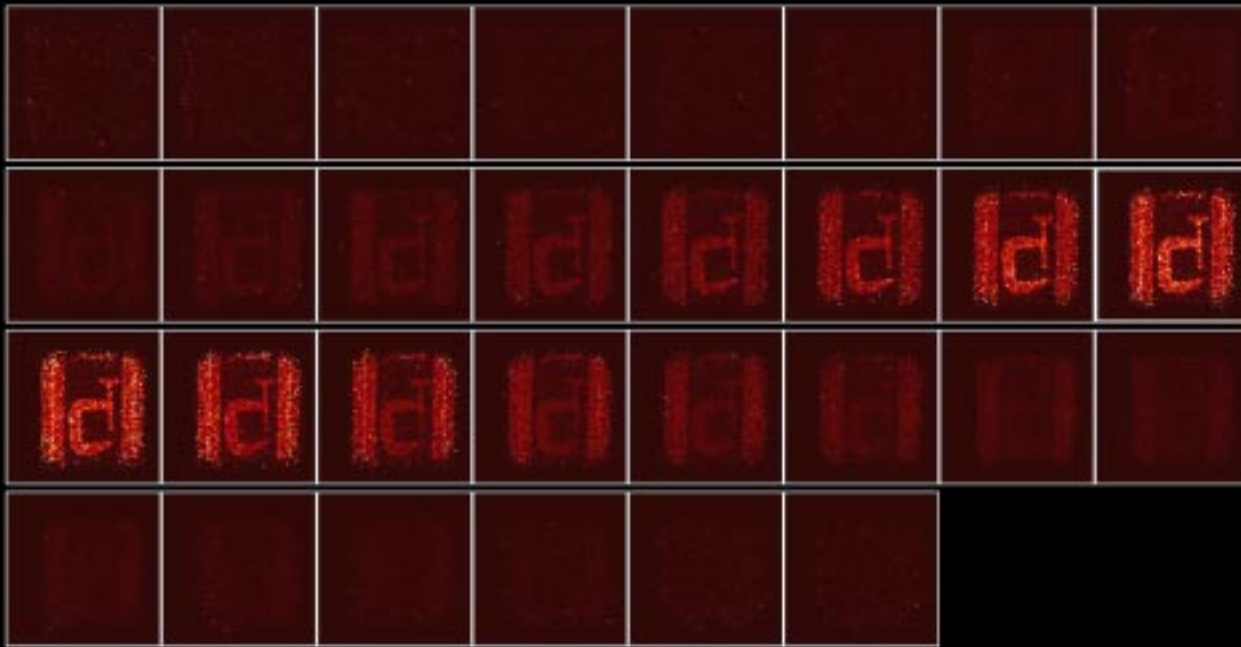
In time, Flynn's group expanded, eventually becoming the Biological and Quantum Physics Group—the SQUID team's current home. Headed by Bob Kraus, the team consists of Michelle Espy, Andrei Matlachov, Petr Volegov, Carl Kumaradas, Chris Carr, Val Armijo, Shaun Newman, Walter Roybal, and Jonatan Mattson. The team is using SQUIDs for a wide range of applications. Most recently, it has begun designing experiments to use a SQUID to measure the neutron's electric dipole moment, measurements that could have a major impact on theories of elementary particles and cosmology. The research Flynn began has made lasting contributions not only to neuroscience and other areas of biophysics but also to defense science and basic physics.



**Bob Kraus** has a Ph.D. in nuclear chemistry from Oregon State University. He first came to Los Alamos as a postdoctoral research fellow in 1984, becoming a technical staff member in 1986 and joining the biophysics group in 1994. Kraus is currently the SQUID team leader and the principal investigator for the MEG project.

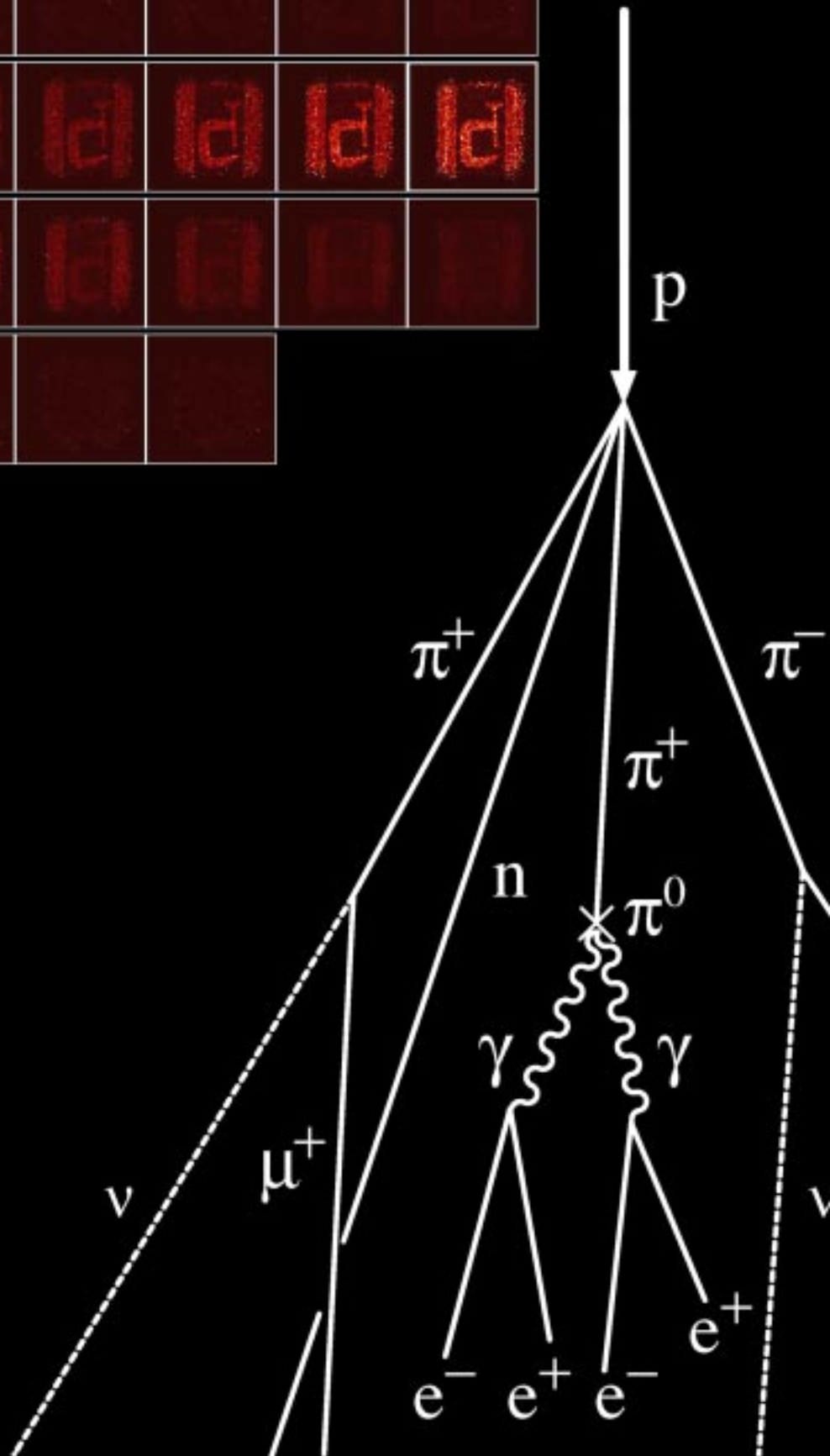


**Michelle Espy** first came to Los Alamos as a graduate student in 1991. After completing a Ph.D. in nuclear physics at the University of Minnesota, she began postdoctoral research in the Los Alamos biophysics group in 1996 and became a technical staff member in 1999.



Cosmic rays are mostly protons from outer space that have kinetic energies as high as that of an apple falling a few meters in Earth's gravitational field. When a cosmic-ray proton strikes an air molecule—typically at an altitude of about 15 kilometers—the result is a shower of energetic particles and radiation. Because the muons produced move at close to the speed of light, their short lifetimes (2.1 microseconds) are extended by the time dilation effect of special relativity, which allows most of them to reach Earth's surface without decaying.

p—proton  
 n—neutron  
 $\pi^+$ ,  $\pi^-$ ,  $\pi^0$ —pions  
 $\mu^+$ ,  $\mu^-$ —muons  
 $e^-$ —electron  
 $e^+$ —positron  
 $\nu$ —neutrino  
 $\gamma$ —gamma ray



# Muon Radiography

## Detecting Nuclear Contraband

by Brian Fishbine

**Muons, elementary particles that shower down on Earth, hold promise as a sensitive means of detecting nuclear materials being smuggled into the country.**

**E**ach minute, about 10,000 muons rain down on every square meter of Earth. These charged subatomic particles are produced when cosmic rays strike air molecules in the upper atmosphere. The cosmic rays themselves are mostly energetic protons produced by the sun, our galaxy, and probably supernova explosions throughout the universe. Thousands of muons pass through us every minute, but they deposit little energy in our bodies and thus make up only a few percent of our natural radiation exposure.

A team of Los Alamos scientists—Konstantin Borozdin, Gary Hogan, Chris Morris, Bill Priedhorsky, Andy Saunders, Larry Schultz, Margaret Teasdale, John Gomez, and Val Armijo—has found a promising way to use this natural source of radiation to detect terrorist attempts to smuggle uranium or plutonium into the country. Either nuclear material could be used to make an atomic bomb (see sidebar on page 16). The technique also detects lead and tungsten, which could be used to shield the gamma rays emitted by nuclear materials—or other radioactive materials—in order to elude detection.

The new technique uses the fact that muons are more strongly deflected, or scattered, by nuclear or gamma-ray-shielding materials than they are by materials such as plastic, glass, and aluminum. This enhanced deflection occurs mainly because the atomic nuclei of nuclear and gamma-ray-shielding materials contain large numbers of protons, which exert large electrostatic forces on muons passing nearby. Since the number of protons is given by the atomic number  $Z$ , such materials are called “high- $Z$ ” materials.

$\mu^-$

## Center for Homeland Security

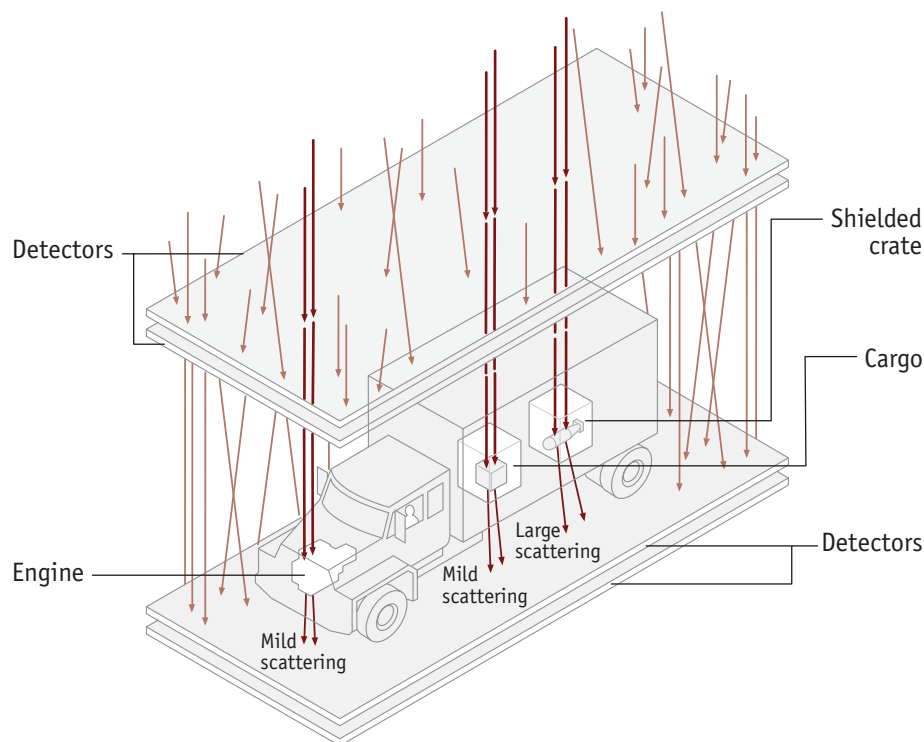
**T**he Laboratory recently established a Center for Homeland Security to coordinate interactions with the new Department of Homeland Security. The Center has four major focus areas: chemical/biological threat reduction, radiological/nuclear threat reduction, critical infrastructure protection, and national infrastructure simulation and analysis. Los Alamos efforts to enhance homeland security have already made significant impacts—from helping identify the strain of anthrax used in the attacks just after September 11 to developing computer simulations that help policymakers assess the vulnerabilities of our nation's infrastructures, including public health. This and the following article showcase current Lab work focused on promoting homeland security.

The deflection is also determined by how many nuclei a muon encounters while passing through the material, which is proportional to the number of nuclei per unit volume—the number density. The number density equals the material's density divided by the mass of its nuclei. The materials that most strongly deflect muons have high atomic numbers *and* high number densities. Several low- and high-Z materials along with their deflections of cosmic-ray muons are listed in the table.

In muon detection, particle detectors above and below a vehicle or container record each muon's path before and after the muon passes through the cargo. A change in a muon's trajectory means the muon has been scattered by the cargo. Using the path information and muon scattering theory, a computer program then constructs a three-dimensional image of the cargo's dense, high-Z objects.

Los Alamos simulations, validated with small-scale experiments (see cover photo), show that cosmic-ray muons can penetrate the 3-millimeter-thick steel walls of a freight truck to detect a block of nuclear or gamma-ray-shielding material 10 centimeters (4 inches) on a side hidden among other cargo, such as livestock or auto parts. The muon scan takes about a minute. People who stay in a vehicle during a scan will receive no more radiation than if they had stayed home in bed. Thus, muon radiography poses no health hazard.

The Los Alamos team can discriminate between different materials even more precisely by measuring muon energies as well as deflections. In computer simulations, this improved technique easily distinguishes between



**Nuclear (high-Z) materials more strongly deflect muons than do the low-Z materials found in typical shipping cargoes. In muon scans, detectors above and below a truck would record each muon's path before and after it passes through the cargo. Using this information and muon scattering theory, a computer program would then calculate and display three-dimensional images of objects with high atomic numbers and number densities—signature properties of nuclear materials.**

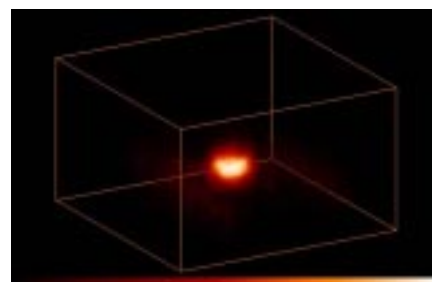
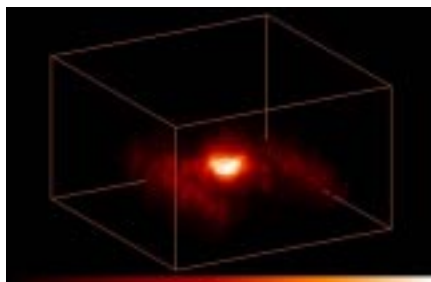
tungsten and steel, for example. Experiments to confirm this discrimination capability are planned for the near future.

## Next Step, Border Inspection?

Border inspectors now use gamma-ray radiography to detect nuclear materials. Because of their high atomic numbers and number densities, nuclear materials strongly absorb gamma rays as well as strongly deflect muons. Thus, nuclear materials are fairly opaque to gamma rays and cast dark shadows in radiographs of vehicles and freight containers.

A gamma-ray scanner uses a radioactive pellet a few millimeters in diameter to produce gamma rays that are energetic and intense enough to scan a large vehicle or container in as little as a few minutes. Although a gamma-ray scan would expose a vehicle's occupants to a negligible dose of radiation—less than a hundredth that of a dental x-ray—occupants are usually removed before scanning, or only the volume of the trailer rig is scanned.

Muon scans will have several advantages over gamma-ray scans. First, the gamma-ray scanner's radioactive pellet must be properly handled and its emissions properly controlled. The pellet must also be replaced after a time about equal to its half-life—the time required for the pellet's radioactivity to decrease to one-half its initial value. Cobalt-60, the most penetrating and hence preferred gamma-ray source, has a half-life of five years. By contrast, cosmic-ray muons do not require radioactive sources that must be replaced. The



Using muon energies, as well as their deflections, produces radiographs that discriminate more precisely between materials. (Left) A muon radiograph based only on deflection data shows an 11-centimeter-diameter tungsten cylinder on a plastic plate with two steel support rails. (Right) A simulated radiograph that includes data on muon energies shows only the tungsten cylinder. This simulation was validated against the experimental image. Combining muon deflection and energy data should enhance the technique's ability to detect both nuclear and shielding materials. (Note: Because of its high number density and atomic number, tungsten is a good nonradioactive surrogate for plutonium and uranium in assessing the capabilities of muon radiography.)

muons are already there, continuously, wherever the inspection site.

Second, because gamma-ray radiography produces two-dimensional images of the cargo, it can be hard to find a block of nuclear material surrounded by, say, a load of steel auto parts. The superimposed gamma-

ray shadows of many objects can prove confusing and create a problem called "clutter." Muon radiography's three-dimensional views overcome this problem.

Third, cosmic-ray muons are also far more penetrating than the gamma rays emitted by even cobalt-60. With

## Comparison of Muon Deflections

Material	Atomic Number	Number Density <sup>*</sup>	Muon Deflection (milliradians) <sup>†</sup>
Plastic			~2
Aluminum	13	6.0	5
Borosilicate glass	—	—	~4
Iron (steel)	26	8.4	11
Tungsten	74	6.3	27
Lead	82	3.3	20
Uranium	92	4.9	29
Plutonium	94	5.0	30

<sup>\*</sup>Units are  $10^{22}$  nuclei per cubic centimeter.

<sup>†</sup>The deflection of a 3-billion-electronvolt muon passing through 10 centimeters of various materials with different atomic numbers. For reference, 30 milliradians is about 1.7 degrees.

an energy of 1 million electronvolts, the gamma rays penetrate about 1 centimeter of lead. With an average energy of 3 billion electronvolts (at sea level), muons penetrate nearly 2 meters of lead. Greater penetration depth means the muons can detect nuclear materials surrounded by greater amounts of high-Z shielding material or clutter.

## Nuclear Threats

Two materials that can be used to make an atomic bomb are plutonium-239 and highly enriched uranium, which contains at least 20 percent of uranium-235. Since both materials have high atomic numbers and number densities, both can be detected by muon or gamma-ray radiography.

Although plutonium-239 can be detected with either neutron detectors or gamma-ray radiography—both techniques are now used for border inspection—uranium-235 presents greater detection problems. It has no significant neutron emission, and its natural gamma-ray emissions can be shielded—usually with a layer of high-Z material such as lead or tungsten. In addition, there is much more highly enriched uranium in the world than there is plutonium-239; thus uranium-235 is more available to terrorists (see sidebar).

Although both muon and gamma-ray radiography can detect highly enriched uranium and its gamma-ray-shielding materials, muon radiography's greater penetration depth and more precise materials discrimination promise enhanced detection capabilities. For this reason, work is now underway to utilize the ubiquitous and benign cosmic-ray muons for detecting nuclear contraband. ■

## A Terrorist Nuclear Attack

One of the most devastating attacks a terrorist group could mount would be to explode an atomic bomb in a city. If exploded in Manhattan during working hours, for example, a bomb with a yield of only 1 kiloton could kill 200,000 people outright and flatten eleven city blocks.

It is believed unlikely—but not impossible—that terrorists could buy a stolen nuclear weapon on the black market. More likely, they will try to obtain fissile materials to make their own bomb. Al Qaeda operatives have repeatedly tried to buy stolen nuclear materials and recruit nuclear-weapon scientists. The extensive materials on nuclear weapons (including crude bomb designs) found in Al Qaeda camps in Afghanistan underscore the group's interest in such weapons.

Regarding the difficulty of making an atomic bomb, former Los Alamos director Harold Agnew said, "If somebody tells you that making a plutonium implosion weapon is easy, he is wrong. And if somebody tells you that making an improvised nuclear device with highly enriched uranium is difficult, he is even more wrong." Contrary to popular belief, terrorists could make either type of bomb without being killed by radiation exposure as they assembled it.

In theory, as little as 4 kilograms (9 pounds) of plutonium would be needed to make a bomb. As little as 16 to 20 kilograms of highly enriched uranium would be needed to make an efficient bomb; a crude bomb could be made with 50 to 100 kilograms of the uranium. By contrast, the world's supply of highly enriched uranium is estimated to be 1,600,000 kilograms; the supply of plutonium, 450,000 kilograms.



**Larry Schultz** has a B.S. in agricultural engineering from Oklahoma State University and an M.S. in electrical engineering from Portland State University. He is pursuing a Ph.D. in electrical engineering at Portland State and has been performing research for his Ph.D. at Los Alamos since 2001.



**Konstantin Borozdin** has an M.S. in nuclear physics from the Moscow Engineering Physics Institute and a Ph.D. in astrophysics from the Moscow Space Research Institute. He came to the Lab as a postdoctoral researcher in 1998 and joined the technical staff in 2001.

# Guarding the Air We Breathe

by Vin LoPresti

**A sentinel against airborne biological threats such as anthrax and smallpox, BASIS offers rapid, high-confidence detection of bioterrorism.**

Rupprecht and Patashnick Co.

**I**t's a sunny morning in late June. Tourists and locals throng midtown Manhattan, near Central Park South. The air carries a mix of aromas—sweet scents from blossoming trees in Central Park, a potpourri of ethnic foods from nearby restaurants, the pungent blend of sauerkraut and roasting hot dogs from a street vendor. But unscented and unnoted by the crowds, the air is also laced with anthrax spores from a bioterrorist attack.

Near the park's entrance, a solitary sentinel—an air sampler—stands between citygoers and a lethal infection. Drawing in the surrounding air, it collects anthrax spores on filters that are analyzed a few hours later with sophisticated DNA techniques. That night, emergency broadcasts from the city's Office of Emergency Management instruct all persons who were near Central Park South that morning where to go for antibiotic treatment.

That lifesaving sentinel is part of BASIS, the Biological Aerosol Sentry and Information System. The air-monitoring system illustrates the best in national laboratory–private enterprise collaboration in the interest of public safety. Now being deployed in cities across the country, it was developed through a partnership between



**BASIS air samplers have been recently deployed in New York City (above and below).**

Los Alamos and Lawrence Livermore National Laboratories and a New York manufacturer of air samplers, Rupprecht and Patashnick Co.

Los Alamos research into air-monitoring systems for detecting dangerous microorganisms dates back to the Gulf War, when the nation as a whole became much more aware of the threat of bioterrorism. Led by J. Wiley Davidson, a talented team of scientists and engineers from D-3 (Strategic Systems Engineering), D-4 (Technology Modeling and Analysis), and NIS-4 (Space Engineering) began designing an aerosol-biothreat detection system in the mid-1990s.

Teaming with Livermore brought the system a giant step closer to becoming a functional technology. The final steps occurred in 1999–2000, with the recruitment of Rupprecht and Patashnick, an Albany company that

manufactures air samplers for the Environmental Protection Agency. By 2001, BASIS was being readied for testing, when the tragic events of September 11 drove its developers into emergency mode. Five months later, they deployed BASIS during the Winter Olympics in Salt Lake City.

## A Sinister Threat

With technologies developed in part at Los Alamos, it is possible to non-invasively detect some terrorist weapons before their use. For example, acoustic detectors can identify chemical weapons in closed containers (see “Sound Solutions” in the Fall 2002 issue of *Research Quarterly*), and muon detectors show promise for detecting the transport of nuclear-weapons components (see article on page 12).

Biological weapons, however, are more sinister in that they are self-enlarging,



using their infected hosts to multiply them. Therefore, terrorists could initiate an attack using miniscule quantities of infectious spores, cells, or viruses. Detecting these small quantities before their release is very difficult.

Thus, at this time, the goal of biological antiterrorism—and the concept behind BASIS—is early and unambiguous release detection, or “detect to treat.” Early detection can save lives—for example, early treatment of anthrax-infected individuals with antibiotics is highly successful in preventing mortality. The time course of anthrax is variable—symptoms may begin to appear at anytime from one to seven days after infection. But the overall recommendation from the Centers for Disease Control and Prevention is emphatic: “Early antibiotic treatment is essential—delay lessens chances for survival.”

## An Integrated System

The visible, “front-end” component of BASIS is a network of strategically deployed air samplers. Sports arenas, airline terminals, bridges and tunnels, government offices, shopping plazas, and busy street corners are all possible locations for samplers. Like the sampler that might protect passersby near Central Park, the goal is to pinpoint the time and place of a biothreat release while characterizing the threat organism’s biology as expeditiously and thoroughly as possible.

A suction pump in the samplers draws outside air through filters with microscopic pores, which capture tiny particles including bacteria and viruses. Two parallel particle-capture systems operate simultaneously. One, called the holder, typically collects particles

for four hours. The other, called a magazine, contains several filters, each of which collects for one hour.

So, for example, the air in a city center during the morning rush hour (6–10 A.M.) would be sampled by five filters per air sampler, a holder filter that had collected for the entire four-hour period and four magazine filters, each having collected for one hour. Only if a holder filter later tests positive for a biothreat organism are its associated magazine filters also tested. This enables hourly biothreat detection while minimizing the number of biochemical assays performed.

## Software

For a deployment of the multiple air samplers needed to strategically blanket a small city or the business center of a larger city, keeping tabs on an air-sampling operation requires more than just pencil and paper. To ensure uninterrupted site monitoring, BASIS operators must sometimes adjust air-sampler operational parameters. For this purpose, samplers communicate with laptop computers running BASIS control software via either shielded coaxial cable, radio frequency, or cellular modems.

The software allows operators to remotely monitor and adjust all critical parameters for either a single sampler or an entire deployed group. For the sake of rapid recognition, these parameters are displayed both numerically and graphically. Using both visual and auditory alarms, the control computers notify BASIS operators of any changes in sampler function that would seriously impair sample collection.

There is also the issue of security. Although each sampler is locked and



BASIS team

**BASIS air sampler deployed during the Winter Olympic Games in Salt Lake City.**



John Flower

**Parallel-path air-filtering system in the current generation of BASIS air samplers.**

**A support team member scans a holder with a laser barcode reader when reloading filters. On either side of the holder are fresh (left) and exposed (right) magazines.**

password-protected, it is clearly imperative that no tampering occur. To ensure tamper-free operation, each sampler sends a “state-of-health” message to the control computers at 10-second intervals.

Another daunting task handled faultlessly by BASIS software is tracking the fate of filters. Just before the end of a holder filter’s collection period, the BASIS operator deploys a replenishment team, which delivers a fresh holder and magazine to the sampler and collects exposed filters. All filters are barcoded so that they can be tracked from deployment through analysis. Fresh and retrieved filters are contained within sealed chain-of-custody bags to ensure that filters are accounted for at all times during transit. The software’s database stores the history of every filter deployed over the course of a given surveillance campaign (and from previous campaigns as well).

## Mobile Biochemistry

The final component in the complex web of BASIS operations is the mobile field laboratory. All holder filters from air samplers undergo testing with the polymerase chain reaction (PCR). This assay uses highly specific bits of DNA known as “primers” that identify an organism’s DNA. Thus, on a filter that contains DNA from staph bacteria (commonly found on everyone’s skin), rhinovirus (a widespread initiator of common cold symptoms), and smallpox virus, primers for smallpox DNA would ignore the DNA of the other organisms and bind to the smallpox DNA with very high specificity. The subsequent addition of an enzyme (thermosensitive DNA polymerase) that duplicates DNA would produce multiple copies of only

the smallpox DNA, and the other irrelevant genomes would be discarded.

A “hit” (positive test) on a holder filter mandates testing of its associated magazine filters, both to confirm the hit and to narrow the time of exposure. Should this confirmation ensue, followup testing is conducted on the target DNA. These more sophisticated assays can sometimes identify the strain of the organism present and also identify—through DNA sequencing—whether the organism has been altered by genetic engineering to make it more virulent or resistant to drugs.

A primary hit requires only eight hours from sample collection through PCR analysis. The followup testing can be done in a few additional hours, making it possible to diagnose and determine the time and place of a bioterrorist attack within twelve hours of the release. In turn, this expeditious assessment makes it much more probable that exposed individuals can be alerted and treated before the onset of symptoms—*in time to save lives*.

## Thwarting, Not Inciting, Terror

Designing an antiterrorist technology entails more than simply fitting together the pieces of a complexly interlocking system like BASIS. For the stakes are high should the system malfunction. That the system must have high sensitivity is obvious, because aerosol releases of bacteria or viruses will quickly become diluted at increasing distances from the release site. And, theoretically, it only takes one bacterial cell or virus to infect an individual, and only one infected individual to start an epidemic. BASIS’ high detection sensitivity was verified



Simulation of the DSU Ops window of BASIS software. The map shows locations of deployed sampling units (DSUs) in Salt Lake City, all of which are functioning in normal air-sampling mode. The air samplers are color-coded by the green square icons on the map and the green numbered rectangles in the upper-left corner of the screen. Moving the cursor over each square icon brings up a small identifier window, such as shown for DSU 24 in the center right of the map. Clicking either this icon or the upper-left rectangular green box “24” opens the subwindow shown at the lower right, which provides instantaneous numerical filtering parameters for sampler 24. At the top, eight tabs provide single-click access to different data windows.

by the U.S. Army in threat-agent tests during 2001.

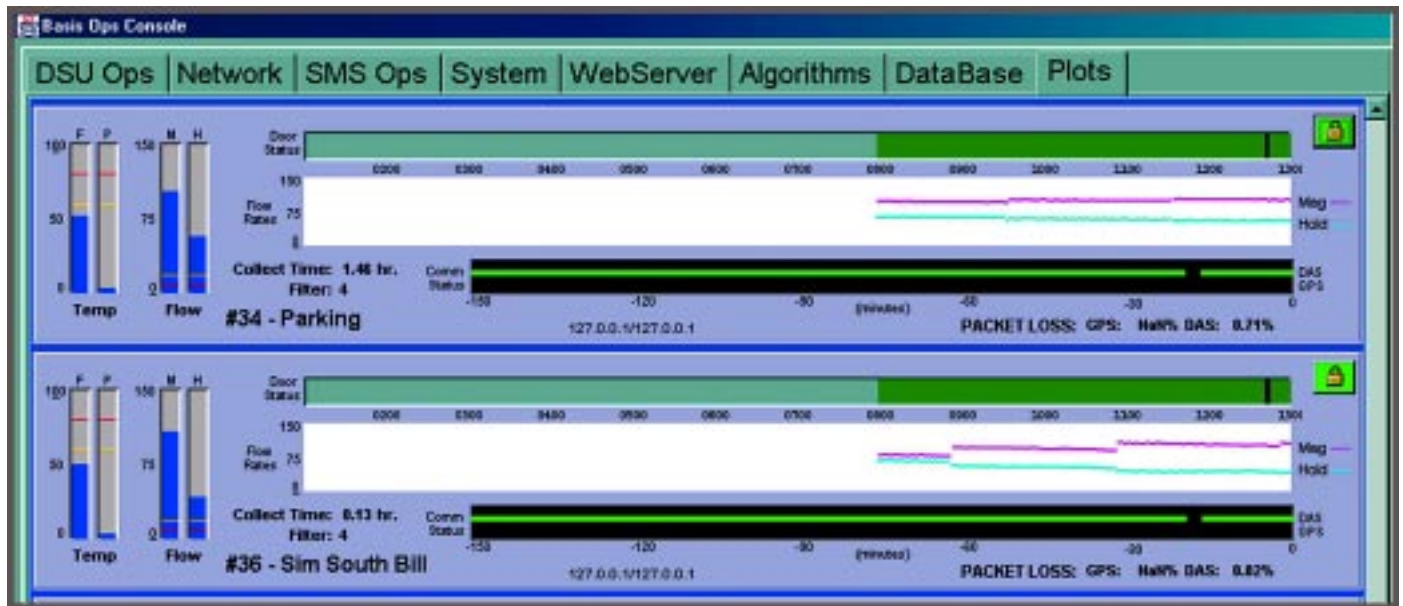
That the system must be infallible may be less obvious. Any technology that reports a terrorist incident where none exists may induce the very panic and social disruption it is intended to thwart. Therefore, the rate of false-positive alarms must be zero or very

nearly so. During deployment in 2002, for about 100,000 screened filters, the rate of false positives in primary assays was less than 0.005 percent—that is, less than one false positive per 20,000 assays. Considering that primary hits on holder filters must be verified both by magazine-filter testing and secondary testing, these numbers should reassure

Americans that their air quality is being monitored by a discriminating sentinel that is unlikely to set off false alarms.

## Bio-Watch and Beyond

In this time of international uncertainty and heightened biothreat anxiety, BASIS is being rapidly deployed nationwide under the name

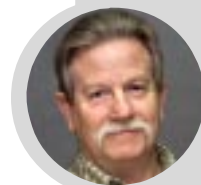


Simulation of BASIS Plots window. Plotted parameters for air samplers 34 and 36 provide a running historical record of filter flow rates, door status, and communication status since their startup. In addition, real-time airflow and temperature data are displayed in the left bar graphs. Red and yellow lines on the bar graphs indicate alert thresholds. At the top, eight tabs provide single-click access to different data windows.

“Bio-Watch.” The deployment is designed to guard against large-scale urban attacks and began this past January in New York. By deploying a smaller, more-portable air sampler and using the testing laboratories affiliated with the Centers for Disease Control and Prevention to perform DNA analysis, the U.S. Department of Homeland Security has quickly pressed the BASIS technology into service.

And while BASIS extends its guard over the nation’s airways, the BASIS team continues its research and development work, seeking to improve all aspects of system performance. Several new versions of BASIS software have already been implemented, and developers are constantly exploring ways to miniaturize samplers and improve their performance, particularly in smog-laden urban environments.

Lightweight, unobtrusive samplers with higher airflow have already been designed and may soon be commonplace in our cities. ■



**J. Wiley Davidson** received a bachelor’s degree in engineering science and an M.S. and Ph.D. in nuclear engineering from the University of Texas, Austin. He served as the BASIS program manager from 1998 until 2002, when he became deputy director for the Los Alamos Center for Homeland Security. Previously, he was deputy group leader of the Systems Analysis Group.

The Los Alamos BASIS development team is a synergistic group of about a dozen individuals of diverse research backgrounds—in physics, chemistry, biophysics, and software engineering—who have melded their talents in the interest of domestic security.

# Modeling an Asteroid Impact

## Did It Kill the Dinosaurs?

by Maureen Oakes

Mounting scientific evidence supports the theory that a large asteroid slammed into Earth about 65 million years ago—killing the dinosaurs and ending the Cretaceous Period. Simulations developed at the Laboratory are providing new insight into this catastrophic event.

**W**hat would happen if a 10-kilometer-diameter asteroid penetrated Earth's crust at a speed of 15 to 20 kilometers per second? The kinetic energy of such an asteroid (more than 6 miles in diameter) would equal the energy of 300 million nuclear weapons and create temperatures hotter than on the sun's surface for several minutes. The expanding fireball of superheated air would immediately wipe out unprotected organisms near the impact and eventually lead to the extinction of many species worldwide.

Immediate effects would include an eardrum-puncturing sonic boom, intense blinding light, severe radiation burns, a crushing blast wave, lethal balls of hot glass, winds

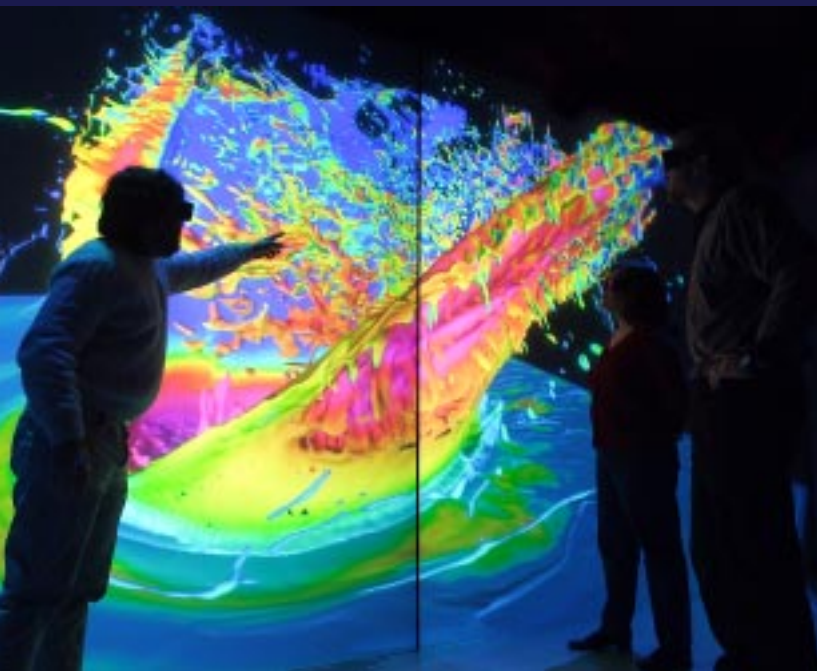


Courtesy of Smithsonian Institution

**Triceratops, a plant-eating dinosaur that lived during the late Cretaceous Period.**

with speeds of hundreds of kilometers per hour, and flash fires. Longer-term effects would alter Earth's climate.

The vapor and debris thrust into the stratosphere would block sunlight for months, lowering global temperatures.



John Flower

Researcher Galen Gisler (left) points out features of the debris curtain formed in a simulation of the Chicxulub asteroid impact. The complex computation for the simulation ran on a section of the Q machine—the new supercomputer in the Nicholas C. Metropolis Center for Modeling and Simulation. Completing the calculations required one million computing hours.

Organisms that could not adapt to this impact version of a “nuclear winter” would die. Since plants derive energy from the sun, they would be affected first. As plants die, the decreased food supply

and oxygen levels would affect the herbivores first, followed by the carnivores and on up the food chain. Birds, fish, mammals, and small reptiles could survive the cold, desolate “winter” if they could burrow underground or live in caves and consume alternate food sources such as seeds, roots, and decaying matter. Most large reptiles would perish.

### 3-D Simulation

After the discovery of the Chicxulub crater at the tip of Mexico’s Yucatan Peninsula, scientists began developing numerical models to understand the sequence of events during the impact and their consequences. The rapidly increasing power of supercomputers and sophistication of simulations facilitated this research.

A team from the Applied Physics Division recently announced the results of a three-dimensional (3-D) simulation created with codes developed at Los Alamos. Galen Gisler, Bob Weaver, and Charles Mader, working with Michael Gittings of Science Applications International Corporation, have generated a dynamic picture of the asteroid impact. They collaborated with Jay Melosh and a research team from

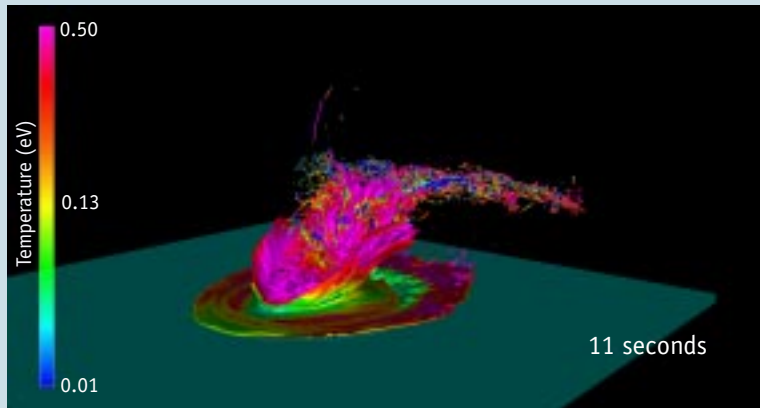
the University of Arizona, who offered advice on the simulation physics and parameters.

Their model focuses on the early-time effects: when the asteroid plunges through Earth’s atmosphere and into water and layers of calcite, granite, and mantle. Craters are formed by the explosion of vaporized rock produced as the asteroid’s kinetic energy is dissipated through contact with Earth’s surface. Steeper impacts result in deeper penetration, but shallower impacts produce larger craters.

To understand the importance of the impact angle, Gisler simulated three different angles: 30, 45, and 60 degrees. He discovered that a lower angle of impact is much more efficient at focusing thermal energy into the troposphere, where Earth’s weather occurs. “I wasn’t smart enough to know this before the simulation,” said Gisler. This focusing occurs mainly downrange, carrying the horizontal momentum of the asteroid. Thus, if the Chicxulub asteroid arrived at a low impact angle from a southerly direction, it could have set fire to all the forests in North America. Indeed, soot deposits are found in the continent’s iridium layer, formed 65 million years ago (see What Killed the Dinosaurs?).

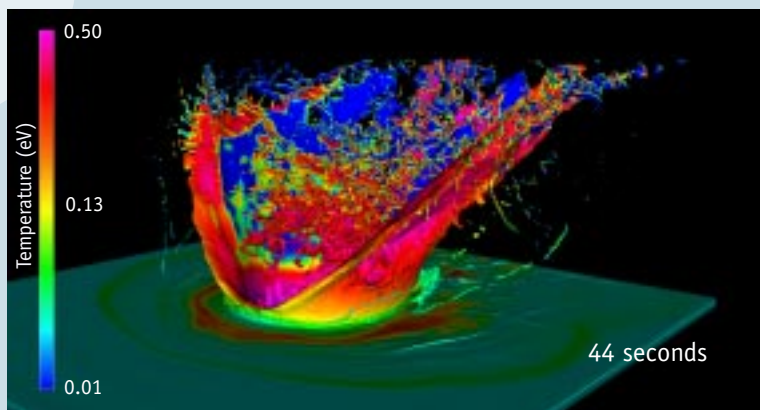
This simulation builds on Gisler’s earlier work in modeling giant impact-generated tidal waves, called tsunamis. He and his co-workers completed the largest and most accurate 3-D models of tsunamis caused by asteroids. They simulated six asteroids of varying sizes crashing into the ocean at a speed of 20 kilometers per second. The simulations have potential value in planning emergency response to the huge waves.

## Simulating the Chicxulub Asteroid Impact

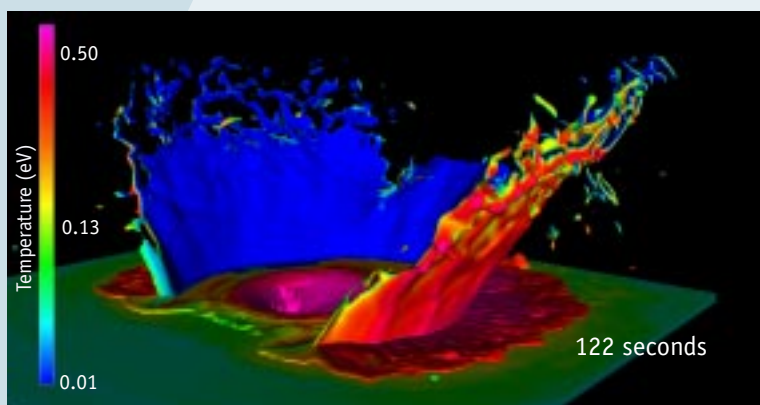


fossilized coral reefs. This image is a perspective rendering of a density isosurface colored by the temperature of materials (0.5 eV = 10,000° F). The scale is set by the back boundary, which is 256 kilometers long; the height of the debris' "rooster tail" is 50 kilometers.

A few seconds after the 10-kilometer-diameter asteroid strikes Earth, billions of tons of very hot debris are lofted into the atmosphere. Much of the debris is directed downrange (to the right and back of the image), carrying the horizontal momentum of the asteroid in this 45-degree impact. The asteroid plunges into 300 meters of water that overlies 3 kilometers of calcite, 30 kilometers of granite, and mantle material—layers that correspond to those of the Chicxulub impact site in the late Cretaceous Period. At that time, the Yucatan Peninsula was on the continental shelf, which consisted mainly of



Less than a minute after impact, the rooster tail has moved far downrange, out of the simulation. The dissipation of the asteroid's kinetic energy produces a stupendous explosion that melts, vaporizes, and ejects a substantial volume of calcite, granite, and water. The dominant feature here is the conical "curtain" of hot debris that has been ejected and is now falling back to Earth. The turbulent material inside this curtain is still being accelerated by the explosion from the crater's excavation.



Two minutes after impact, the debris curtain has separated from the rim of the still-forming crater as debris in the curtain falls to Earth. The debris is deposited asymmetrically around the crater, with more falling downrange than uprange. The distribution of material in the ejecta can be used to determine the direction and angle of impact of the asteroid. Cores that have been obtained around the Chicxulub impact site are consistent with a southerly direction for the impact. Future drilling—guided by simulations such as these—may help to determine more definitively the geometry of impact.

## Beyond Dinosaurs

Scientists around the globe are keeping an eye on the sky. NASA has a Near-Earth Objects program that tracks asteroids. Two of the many projects sponsored by the program are the Lowell Observatory Near-Earth Object Search near Flagstaff, Arizona, and the Lincoln Near-Earth Asteroid Research near Socorro, New Mexico. These observatories have identified and obtained orbital parameters for an estimated 90 percent of all asteroids in the solar system larger than 1 kilometer in diameter. In Vienna, the International Monitoring System is tuned to detect sound waves created by exploding meteors in the atmosphere—about thirty per year—with frequencies too low to be audible to the human ear. Some of these meteors are as small as basketballs.

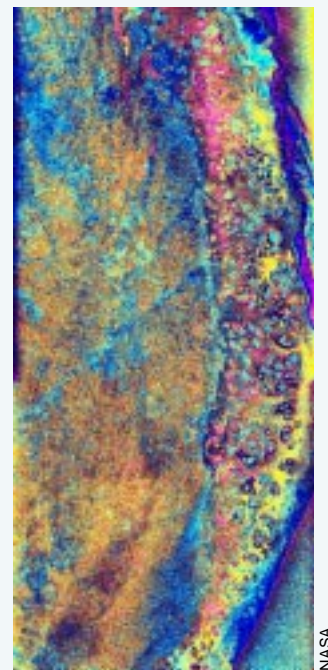
An asteroid impact on land could cause vast forest fires such as the famous Tunguska event of 1908, when such an impact devastated 2,000 square kilometers of Siberian forest. It could also cause global climate changes, possibly severe enough to destroy civilization. A marine impact could generate a tsunami capable of inundating the coasts on both sides of the ocean.

Destructive impacts such as Tunguska are likely to happen but once every thousand years. And there is only a 1 in 200,000 chance that a 1-kilometer-diameter asteroid will hit Earth in a given year. Still, scientists do not want to be caught off guard. They would like to be able to identify risks, predict the occurrence of significant impacts, prepare for future impacts, and even mitigate the effects of an impact. Gisler and his team are contributing to this research. ■

## What Killed the Dinosaurs?

**I**n 1980, father and son Louis and Walter Alvarez from the University of California went on a geology expedition in Italy. Their mission: to investigate the layer in Earth's crust that marks the end of the Cretaceous Period. They discovered that the layer contains an unusually high level of iridium, an element that is rare on Earth but abundant in asteroids. Later investigation revealed that the iridium in this layer extends worldwide. The duo hypothesized that its global presence resulted from a giant asteroid striking Earth. Furthermore, they suggested that a series of events after the impact was responsible for a major biological catastrophe—the extinction of more than 50 percent of Earth's plant and animal species, including the dinosaurs.

The search to find the impact crater then began, with scientists using technology such as seismic-monitoring equipment designed for oil exploration. Several years later, Pemex, the national Mexican oil drilling company, discovered a huge crater at the tip of the Yucatan Peninsula, near the village of Chicxulub. Hidden under a thick layer of sediment deposited over the past 65 million years, the crater lies partly on land and partly under the ocean. It is some 170 kilometers in diameter, or more than 100 miles across.



**A radar image of the south-west portion of the buried Chicxulub impact crater.**



John Flower

**Galen Gisler** received a B.S. in physics from Yale University and a Ph.D. in astrophysics from the University of Cambridge. He has been at Los Alamos since 1981. Before studying asteroid impacts, he worked in the fields of astrophysics, plasma physics, adaptive processing, and astronomical transients.

# Spotlight

Los Alamos  
in the News

## Patent and Licensing Awards



*outStanding  
innOvation*

Laboratory researchers whose innovations were patented or licensed in 2002 were recognized at the fifth annual Laboratory Patent and Licensing Awards ceremony in February. Sponsored by the Industrial Business Development Division, the ceremony honored 130 current and former employees for their contributions to the Lab's portfolio of patented, copyrighted, and licensable technologies. The 2002 Distinguished Patent and Licensing Awards were also presented.

The 2002 Distinguished Patent Award was shared by Basil Swanson and former Los Alamos staff member Xuedong Song of the Bioscience Division for their patent of the Triggered Optical Biosensor. By amplifying specific binding events between fluorescence molecules, the biosensor can detect protein toxins, viruses, antibodies, and other biomolecules. Such sensor technology is critical to defending against threats of bioterrorism and has medical applications in diagnosing respiratory diseases. The Distinguished Patent Award recognizes inventors whose work exemplifies significant technical advance, adaptability to public use, and noteworthy value to the Lab's mission.

The 2002 Distinguished Licensing Award went to Benjamin Warner of the Chemistry Division. Warner's work, which spans radiation dosimetry, micro-x-ray fluorescence for drug discovery, and electrochromic (tinting) windows, has led to numerous commercialization ventures for the Laboratory. Warner has eleven patent disclosures and five pending patent applications, most of which were submitted in the past two years. He has actively pursued licensing opportunities, identifying markets for his varied inventions and promoting collaboration with potential licensees. The Distinguished Licensing Award recognizes inventors for outstanding success in transferring Lab technologies to the public and private sectors.

Last year, seventy-five U.S. patents were issued for Los Alamos



The 2002 Distinguished Patent and Licensing Awards.

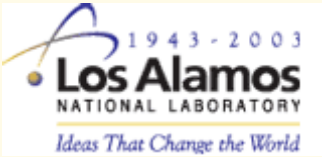


Lab winners of the 2002 Distinguished Patent and Licensing Awards, Basil Swanson (left) and Benjamin Warner (right).

inventions, thirty-one commercial licenses were approved, and \$1.43 million in licensing income was generated. The Lab's portfolio now contains more than 600 licenses with academia, government agencies, and other nonprofit organizations as well as more than 150 commercial licenses. Since 1988, the Lab's licensing program has generated more than \$7.5 million in royalties. Approximately two-thirds of that income has gone to fund research, education, and technology transfer activities at the Laboratory. The remainder has gone to the innovators.

—Todd Hanson

Laboratory Turns 60



On April 7, the Laboratory kicked off its 60th anniversary celebration. Festivities began with an anniversary address by Interim Laboratory Director Pete Nanos, who discussed the Lab's past and future.

Following his talk, Nanos moderated a forum of former Lab directors that included Harold Agnew, Sig Hecker, and John Browne. John Hopkins, an associate director under Donald Kerr and Sig Hecker, represented Kerr in the forum. The directors discussed key accomplishments and challenges that occurred during their tenures. At an afternoon ceremony, Nanos awarded Los Alamos National Laboratory Medals to George Cowan and Louis Rosen in recognition of their distinguished scientific service to both the Lab and the nation.



Forum of directors:  
(From left) Harold Agnew, John Hopkins, Pete Nanos, Sig Hecker, and John Browne.

The Laboratory was founded six decades ago, although historians disagree on the precise date. The formal contract between the federal government and the University of California establishing the Laboratory was signed on April 20, 1943. But the first meeting of the scientific committee headed by the Lab's founding director, J. Robert Oppenheimer, was held on March 6. Special events during the next six months will celebrate the accomplishments of Lab employees and the support of neighboring communities over the past sixty years.

As part of these festivities, the Laboratory and the University of California have scheduled an Anniversary Recognition Ceremony on April 22. Special guests invited include New Mexico's two U.S. senators, Pete Domenici and Jeff Bingaman, other members of Congress, many state and local officials, and officials from the Department of Energy and the National Nuclear Security Administration. Later in the day, two major new Lab facilities will be dedicated: the Nonproliferation and International Security Center and the Dual-Axis Radiographic Hydrodynamics Test (DARHT) facility.